Storm Event and Continuous Modeling of an Illinois Watershed to Evaluate Surface Water Supplies

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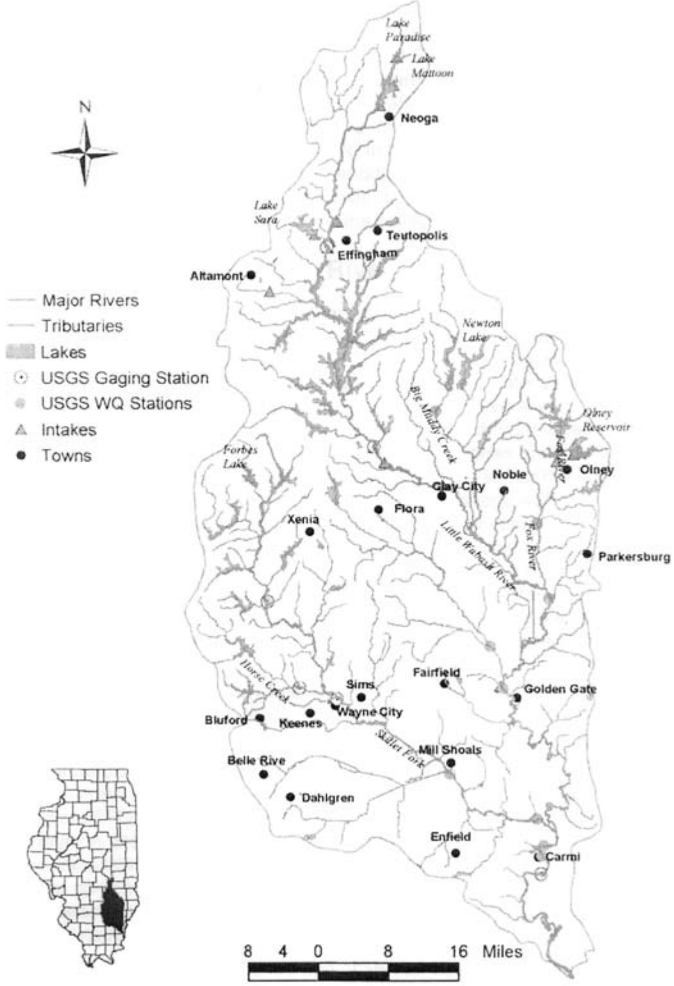
Land degradation and nonpoint source pollution from agriculture can affect the quality and quantity of surface water, and runoff from storm events can increase the effect. Because of this concern, researchers at the Midwest Technology Assistance Center (MTAC) for Small Public Water Systems began searching for a watershed-scale hydrologic and nonpoint-source pollution computerized model that they could enhance with storm-event algorithms. One of their main goals was to use an augmented version of a watershed model as a source water protection and assessment tool for small public water supply systems.

Nonpoint-source pollution from agriculture is the most widespread source of impairment to the Mississippi River watershed. In Illinois, agriculture has been identified as a particularly severe offender, and some drinking water supplies suffer from high concentrations of sediment, nitrate-nitrogen, and other agriculturally related chemicals that exceed health standards. The sediment problem is so severe that it also seriously reduces the water supply capacities of Illinois' lakes and reservoirs. Many other Midwestern U.S. streams and rivers that receive runoff from their industrial-scale agricultural watersheds have elevated concentrations of nitrate-nitrogen, and these streams and rivers drain into the Gulf of Mexico, potentially spreading pollution.



Watershed Models Simulate Actual Events

Computerized watershed models are used to simulate actual events that can have an effect on the watershed. Currently, however, there is no leading watershed model that is capable of simulating all of the situations that can have an effect on the watershed, such as hydrology, upland soil and stream bank erosion, sediment transport, and the transport of nutrients and pesticides. Being able to simulate these circumstances is necessary for researchers to assess water quality and quantity problems before they can make the best management decisions to minimize them.

The U.S. Department of Agriculture's (USDA) Agricultural Research Service (ARS) model Soil and Water Assessment Tool (SWAT), which is also used in of the U.S. Environmental Protection Agency's (EPA) Better Assessment Science Integrating Point and Nonpoint Sources (BASINS), was found to be the most promising watershed model to develop into something more comprehensive.

SWAT is a public domain river-basin scale model that was developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds with varying soils, land use, and management conditions over long periods of time. A research team from the Illinois State Water Survey and USDA's ARS developed a study of how to best augment SWAT.

SWAT's major shortcoming is that it is mainly a daily time-step model and was not initially formulated to simulate storm events. The output from a smaller time-step (e.g., minutes) model predicts how a lake or river would respond to changing rainfall, effluent discharges, and other phenomena. However, the use of daily data can mask high rainfall intensities and might not be able to simulate runoff close to the real values.

Enhancing SWAT

The research team planned to augment the SWAT by adding better scenarios to simulate storm events and stream bank erosion and by incorporating high-resolution precipitation data. They then applied the enhanced SWAT to a major watershed in Illinois that has small public water supply systems using surface water, employed it to assess water quantities and qualities at the surface water supply intakes, and evaluated various management scenarios.

Because of its agricultural nature, the research team chose the Little Wabash River watershed in southeastern Illinois to apply SWAT enhancements. The Little Wabash River watershed is the principal tributary of the Wabash River and includes seven small and three large public water supply systems that use surface water (Altamont, Clay City, Fairfield, Flora, Neoga, Olney, Wayne City, Effingham, Mattoon, and Rend Lake Intercity Water Systems).

The river's developmental history shows that the low level of water resources planning retarded watershed growth, resulting in a very rural and sparsely populated agricultural watershed. According to the research team, sediment, nutrient enrichment, and other agricultural chemicals impair nearly every mile of the Little Wabash River. The team found detectable levels of atrazine in all of the water supplies.

They gathered data from EPA's BASINS database to define watershed and sub-watershed boundaries, compute their dimensions and representative slopes, and estimate various model parameters. The researchers then divided the watershed into 88 sub-watersheds that were grouped based on climate, hydrologic response units (HRU), ponds, groundwater, and main channels. HRUs are land areas within the sub-basin that are lumped together because they are uniquely similar in land cover, soil, and management. The team then used this information to simulate storm events.

Why are storm events important?

Storm events are known to increase environmental damage from agricultural practices, transporting sediment and chemicals downstream. They generate and carry much, if not most, of yearly sediment and chemical loads. Storm event modeling procedures have proven robust and effective for analyzing impacts of storm events, including severe actual or designed single-event storms, on watershed management practices.

Through their background research, the team found that the SWAT watershed-scale, long-term, continuous-simulation model would be the most promising watershed model to augment. The enhanced model could then be used as a source-water protection and assessment tool for small public water supply systems that use surface water.

The storm event model they developed showed promise when they applied it to the Little Wabash River watershed in Illinois. Calibration results showed that the storm event model predicted the high flows, including peak and runoff volume for a period of 35 days with a major rainfall event and few smaller events, better than the existing SWAT continuous model with daily time steps.

Conclusions

The research team notes that model parameters will require further adjustment or calibration for better model predictions. Model adjustment and calibration is currently in progress along with further investigations of SWAT enhancements, including storm event erosion, sediment transport and water quality simulations, and applications of the model to the Little Wabash River watershed for both long-term and storm event water quantity and quality evaluations. These evaluations will occur throughout the watershed, including intakes of small public water supply systems under existing and alternative land use and management practices.

SWAT enhancement work will continue to involve storm event simulations, including developing proper procedures for converting SWAT's existing sub-basins and HRUs into overland and channel flow segmentation schemes.

For More Information

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MTAC provides technical assistance to small public water systems as well as water systems serving Native American communities. Their mission is to provide small system administrators and operators with the information necessary to make informed decisions about planning, financing, selecting, and implementing technological solutions to address needs.

EPA's BASINS database information is available at www.epa.gov/OST/BASINS/.